AR Bike Helmet

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Group Information

Group ID: 10

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Executive Summary

Cycling usership in Canada has increased significantly in recent years. More specifically, in Victoria and the surrounding area bike users have doubled in population since 2015 and the number of cyclists that use their bike as a regular method of travel has significantly increased [1] [2]. This helmet was designed and built for the purpose of helping not only the Victorian community but the cycling community. We feel that one of the best ways to encourage cycling in transportation and recreation is to help riders feel safe on the road. This project was driven by our team's primary focus on reducing bike & car related crashes to promote biking for transportation in urban areas. In recent studies it has been reported that many crashes were due to bike riders navigating in traffic unaware of vehicles approaching them from the rear [3] [4]. With the increasing number of cyclists on the road year to year, evidently there is an ever-increasing number of accidents on our roadways. Furthermore, the development and integration of E-Bikes in modern society has allowed for a cyclist's maximum speed to greatly increase, as a result a greater emphasis is put on rider safety. Thus, there is a large need for tools to be developed to assist in the safety and experience of an everyday bike rider.

Our approach to the hardware design for this project can be more easily explained under three categories: computer vision (CV), heads-up display (HUD), and power supply. The computer vision aspect of this project is intended to identify and track motor vehicles approaching the cyclist from the rear. The CV module was trained to recognize the front facing view of a car and identify it as left or right side approaching. This information is then conveyed to the Arduino Nano microcontroller via I2C communication. The microcontroller is then responsible for signaling the OLED screen to display an arrow with the direction as determined by the Huskylens information. The OLED screen is positioned so that the image being displayed is reflected off a tinted lens and in the rider’s field of view. All the components in our design are powered by a single 18650 LiPo cell taken from an existing power bank originally proposed for charging cell phones or other devices via USB. Each hardware component was in part selected for its ability to be discreetly integrated into the current helmet design. It was important to the designers that such wearable tech provides its service in the least intrusive way possible.

The outcome of our project revealed a working prototype which was tested in real world scenarios. The helmet successfully detected vehicles approaching from the users rear and effectively notified the rider with a virtual arrow image in their field of view. The advent of augmented reality technologies for cyclists could have a profound effect on cyclist usership, the overall physical health of a population, and mitigation of traffic congestion. Throughout the course of this project many challenges and discoveries presented themselves. In this, many avenues for improvement and future work in the design were realized. Ultimately, we would like to see that the development of such a project could act as a precursor to future technologies with similar goals and motives within the cycling community.

I Introduction

Biking to work is one of the most environmentally friendly ways to travel for day-to-day commuting, however, the potential for injury from collisions with vehicles presents a vital problem to be addressed. It is important to minimize the probability of accidents between cyclists and vehicles if the total population of cyclists is to increase. One solution would be to increase the rider’s awareness, this can be accomplished by attaching mirrors to the bike handlebars or onto the rider’s helmet. These solutions do help the cyclist, but at the same time disrupt their field of view and divert their attention from the road. Therefore, this project will focus on creating a blind spot detection device for the rider, utilizing a transparent Heads-Up Display (HUD) to indicate which side the vehicle is approaching from. Thus, keeping the rider’s attention focused on the road, not obstructing movement or vision, maintaining the bike's aesthetics, and simultaneously detecting upcoming cars on either side of the cyclist. This project is intended to act in the public's interest by creating a safer environment for cyclists to navigate roadways. The project will be conducted diligently in accordance with the Engineers and Geoscientists British Columbia (EGBC) code of ethics (see appendix A) by implementing good documentation standards and revision tracking using remote repositories. This project also acts in the interest of public safety and environmental preservation by heightening riders' awareness and increasing the number of cyclists in everyday travel.

Potential User

The potential user base for this device is any person who rides or wants to ride a bicycle for either everyday travel, or occasional riding. The device is implemented into the design of a regular bike helmet, meaning anyone can use it to their advantage. The device is light and compact enough for adults and children to use with ease. Also, there is no user interface or user control required, simply power on the helmet and secure it to the rider's head for a fully functional bicycle blind spot detection.

II Objectives

The following is the list of objectives intended by this project:

- To design a system to increase bicycle rider’s spatial awareness.
- To reduce the number of collisions between riders and motorists.
- To increase rider safety.
- To train the HuskyLens computer vision module to detect upcoming cars.
- To create the code to interface with the HuskyLens and display via I2C.
- To design a basic HUD using reflected images and small displays.
- To implement a small rechargeable battery to power the system.
- To Prototype a functioning AR bike helmet with blind spot detection.

III Design Specifications

The following sections are intended to break up the overall design into more specific categories to provide a more in-depth explanation. The subsequent categories will expand upon the computer vision aspect of this project, the microcontroller used in transferring output from the CV module to useful input for the rider, the heads-up display itself, and lastly the power supply for the system.

Computer Vision

The Huskylens has a built-in Kendryte K210 AI chip that uses machine learning technology to enable the device to recognize specified objects [5]. With its OV2640 2.0 Megapixel camera, the Huskylens can capture fast moving objects in adequate quality [5]. In this scenario the objects to be detected will be motor vehicles moving at urban road speeds which for this purpose is being assumed to be less than 60km/h. The Huskylens can easily be trained to recognize objects such as the front facing view of a car. The Huskylens will then draw a box around the identified object and information can be established from the location of this box in the Hiskylens' field of view. The information can be used to differentiate between objects on the left or right half of its view and will communicate such information with the rest of the system. Additionally, the Huskylens can identify the size of the box it draws around the object. The size can be compared frame to frame to indicate whether the object is approaching. Evidently, an approaching car will increase in size from one frame to the next. These are all important attributes of the Huskylens in object tracking. The Huskylens is also capable of connecting to a main control board such as the Arduino Nano, through I2C and UART ports [5]. This allowed the entire system to be conveniently controlled through the Arduino Nano. The code was written and successfully tested with the aid of a serial monitor to ensure the I2C communication bus was functioning between the Huskylens, OLED display, and microcontroller. Moreover, the Huskylens' physical dimensions are 2.05"x1.75" and therefore due to its smaller size, will be much more easily integrated as wearable tech [5].

Microcontroller

It was decided that the Arduino nano will be used for its small form factor, power efficiency, and 5V IO which would help communicate with peripherals, most of which are built for Arduinos. Another reason for selecting the Arduino was that peripheral libraries are typically built for Arduino first, so we are less likely to run into compatibility issues with any libraries and peripherals.

Heads-Up Display (HUD)

The visor attachment was designed in Fusion 360 and 3D printed for the prototype. The visor attachment is used to support the lens and situate it in front of the rider's view. In this manner the AR display will be more easily viewed by the user. Moreover, as a team it was important to keep in mind that the design was intended to be as discrete and lightweight as possible for the user base. The IZOKEE 0.96" 128x64 OLED I2C 3.3-5V display is projected from the mounting location just above the user's right eye [6]. The previously mentioned mounting location allows for the OLED screen to maintain brightness when being reflected off the lens. The OLED is above the rider's peripheral vision and out of sight. The general rationale behind this concept is to reflect the OLED off the visor's inner surface at an appropriate angle for the rider to observe. One of the bigger challenges to the project was making a feasible AR display. The optimal location for the OLED screen to be projected into the rider's view was determined through trial and error. The best results were observed when the OLED was very close to the visor to maintain light intensity and the incident angle was 90 degrees to the rider's eye to avoid image distortion. Furthermore, it was important that the arrow projection was visible to only one eye or else the projection would be "doubled" and appear out of focus.

Battery Pack

The power supply for the helmet is provided by a single 18650 LiPo cell harvested from an existing power bank. The PCB housed within the original pack was also used in the design as it was necessary for voltage regulation, recharging, and USB connection. The battery's function was tested by powering up the complete and running system with it and leaving it running until the battery was drained. The single 18650 cell supplied plenty of power storage for testing and prototyping purposes. The device was kept powered for up to 5-6 hours without recharging. The power supply also incorporates a small PCB taken from the original Yoobaoo Thunder power bank [7]. The circuitry boosts 3.7V LiPo battery cell to 5V at the output and allows for the cell to be charged through USB connection [7]. The same USB port also enables the power supply to be delivered to the peripheral hardware components. The calculated battery lifetime was 6 hours. The single battery cell used to power our helmet can be recharged through a micro-USB port located on an external PCB. The port can be accessed from the back of the helmet and can be conveniently charged from a household outlet. The battery can be fully charged in 2.6 hours and requires 1A of current capacity.

IV Literature Survey

The following will discuss the details learned by review of discovered literature or each problem addressed.

Problem 1: Object Tracking and Computer Vision

In the initial stages of our project, an obvious obstacle for developing a bike helmet capable of detecting and notifying cyclists of traffic approaching from behind is providing the necessary computational intelligence. Extensive research on the topic presented a few solutions worth pursuing. OpenCV is a library of programming functions purposed for real-time computer vision applications [8]. Implementing this software with a Raspberry Pi and Pi-camera pair would allow for object recognition capabilities. However, the frame rate to the Raspberry Pi is not suitable for moving objects let alone fast-moving objects [8]. From research the Raspberry Pi is documented to get up to 0.9 frames per second which is not fast enough to constitute real-time detection [8].

Upon conducting further research regarding computer vision methods and hardware for object tracking applications, the DFRobot Huskylens was found as a viable solution for our implementation. The Huskylens has a built-in Kendryte K210 AI chip that uses machine learning technology to enable the device to recognize specified objects [5]. With its OV2640 2.0 Megapixel camera, the Huskylens can capture fast moving objects [5]. In this scenario the object will be motor vehicles moving at urban road speeds which for this purpose is being assumed to be less than 60km/h. The Huskylens is also capable of connecting to a main control board such as the Arduino Nano, through I2C and UART ports [5]. This will allow the entire system to be conveniently controlled through the Arduino Nano. Moreover, the Huskylens' dimensions are 2.05"x1.75" and therefore due to its smaller size, will be much more easily integrated into wearable tech [5].

Problem 2: Indicator

A significant advantage this design will have when compared to existing blind spot detection, such as mirrors, is that riders do not need to divert their attention from the road to see oncoming vehicles. By projecting an indicator onto a mounted visor, riders can keep their attention on the road. This also gives future applications for speed indication, or other ride information such as Strava or Google Maps integration.

Initially the group found a keychain projector from Brookstone, measuring 4" x 3.5" with a Micro HDMI video input and Micro USB for power input. Using this projector would simplify the power system as it would all run off 5V, but we would need a way to convert an SPI signal from the Arduino into HDMI through a breakout board [9]. A more significant issue is that these projectors are no longer being produced, and we were not able to find any for sale from second-hand sellers.

To be considered next are transparent OLED displays (TOLED) which are 70% transparent when not displaying any pixels. These have great potential and would be able to be used like glasses, eliminating any need for adjusting reflection angles. Unfortunately, the only sellers were based out of China, and would have taken months to arrive, assuming no shipping issues; additionally, there was not sufficient documentation on use of these TOLED displays, as they are a newer technology [10].

The most pragmatic solution is an OLED display from Amazon. An IZOKEE 0.96” 128x64 pixel display with I2C support seemed to provide an affordable solution [6]. This unit was selected since OLEDs are commonly used in hobby projects so there are plenty of online resources and documentation to support them. Also, Amazon can expediently ship them, with low costs per unit. Like the projector, this would be mounted outside the rider's field of view and an arrow is reflected off a tinted visor to indicate from which side the vehicle is approaching.

Problem 3: Power Supply

Another important aspect for wearable tech, such as a helmet, is a suitable power supply. The power supply should be lightweight, small, and capable of supplying at least 5V power for the Arduino and Huskylens. The power supply must also be either rechargeable or replaceable.

The first option considered was to use disposable batteries. A single 9V battery was to be used as the Arduino can convert it to 5V using its onboard regulator. This option was quickly reconsidered, as 9V batteries have a high price point and would create unnecessary waste, and additional voltage supply incompatibilities to the peripherals. Additionally, anyone using the helmet would not want to worry if their helmet battery would unknowingly die during a ride, failing to notify them of an incoming vehicle. This ties into principle 1 of the EGBC code of ethics: Act in the public's interest (see appendix A).

5V portable power banks exist as phone chargers. These power banks can be repurposed to supply the hardware used in this project. It was decided that using a power bank with multiple 18650 cells in parallel provides an ideal solution. Keeping only one 2600mAh cell to reduce size and weight was found to supply adequate power for the system. Also, the voltage boost and charging circuitry from the original power bank was used in the helmet's power supply. This power bank came equipped with two USB ports which delivered 5V up to 1A. With the Huskylens consuming around 230mA [5], the Arduino consuming around 16mA [11], and the OLED consuming 8mA [12], a total of 255mA is required at 5V. Since the cell is a 3.7V LiPo with 2600mAh or 9.6 Watt Hours, converted to 5V with the boost converter, this setup can supply 1828mAh assuming 95% efficiency. This is enough to power the helmet for over 7 Hours.

The power bank that was disassembled was a Yoobao Thunder, with a total capacity of 13,000mAh [7]. The used components from this power bank were a single 18650 battery and the charging/regulator PCB. This model was chosen as it was readily available and did not use a pouch-style LiPo battery.

V Team Duties & Project Planning

This section will describe the project duties distributed between the 3 group members: Jordan, Branden, and Matt. Figure 1 has these duties in table form with their respective due dates.

3D printing, Assembling, and Code

Jordan designed and 3D printed the custom components necessary for the project, as well as assembled the final system and wrote the microcontroller's code.

The component design was done using the student version of Autodesk's Fusion 360 software, where the 3D design of the following components is made:

- Visor mount
- Visor mount braces
- Huskylens mount

Each of these components required specific dimensioning to obtain the correct angles for the HUD visor and the Huskylens camera angle. The files must be exported to .stl format for the 3D printer's slicing software (Cura) to use. Once the models were sliced they were printed using polylactic acid (PLA) filament and assembled on the helmet. The Arduino microcontroller's code included the appropriate libraries to interface with the I2C serial protocol, and to each specific peripheral (Huskylens and OLED display). The embedded C code is also responsible for determining which side the approaching car is coming from and estimate the distance from the rider. Once the distance and side are determined, the correct pixel bitmap is sent to the OLED display via I2C to inform the user of the oncoming vehicle.

Battery Pack and Microcontroller

Matt focused on the design and development of the battery pack and its associated wiring. As well as the selection of the main microcontroller for the system.

The input voltage ranges of each peripheral must be determined before a battery pack design can commence. Once the ideal voltage supply was selected, the battery capacity is then determined based on the total current draw at supply voltage of each peripheral, then the battery cell type was selected. The charging and output voltage converter/regulator system was then selected based on the required operating voltage, charging voltage, and cell voltage. The microcontroller is selected next to meet the following criteria:

- Low power consumption
- Compatible serial protocols
- Small form factor
- Cost effective
- Easy prototyping

Once a list of microcontrollers was presented to the group, each having met the previously listed criteria, the ideal microcontroller was selected. The microcontroller is responsible for communicating with the display and computer vision module as well as processing the information received from the CV system and determining how to indicate the rider.

Computer Vision and HUD

The design of the HUD and selection of the computer vision module was completed by Branden. Both systems are critical for the correct operation of the features required by the prototype design.

The HUD is responsible for displaying the information to the rider without disrupting their vision or diverting attention and required some intricate optics design to accomplish. The visor was selected to produce a reflected image to the user's eye, while also maintaining focus and legibility. The display selected to produce the information to be projected had to be small enough to conceal into the helmet's design, but also be required to interface via serial bus to the microcontroller for easy implementation. Lastly, the following optimal physical characteristics where required to properly create the virtual image in the rider's field of view:

- Distance from the visor's reflection surface
- Angle of the visor
- Angle of the display
- Orientation of the display
- Additional shading (if required)

Once each of these parameters was determined the HUD was designed to function as desired. The CV module is used to detect the oncoming traffic and interface with the microcontroller via serial protocol. It was also required to be small and have a low power consumption to not drain the limited battery power. Additionally, the CV module selected had to be able to be trained to detect an oncoming vehicle and track the object as it crosses its field of view.

Challenges

Only a couple aspects of this project encountered challenges large enough to be discussed here. The HUD design proved most difficult to implement due to the many uncertain parameters at the time of design such as unknown mounting surfaces, unknown visor distance from the rider, and unknown environmental factors (ambient light, vibration, and eyesight characteristics). So, the main design of the HUD was delayed until the rest of the systems were designed. Once the visor's distance from the user's face was determined and mounting surfaces were designed and 3D printed, the design of the HUD could begin. The initial approach was to use known optics equations to calculate the angle of incidence and distance to create an ideal virtual image for the rider. However, since the complex curvature of the visor was unknown and could not effectively be altered to match any dimensions analyzed in the calculations, trial and error was used to find the ideal display placement in correlation to visor angle. The display had a 3D printed mounting platform designed and printed to ensure stable and consistent operation of the HUD. The second challenge encountered was the design and printing of the visor mount. Since no CAD model of the helmet or visor was supplied by the manufacturers, the curvatures of the frames were difficult to measure and model in Fusion 360. However, since the PLA filament is relatively cost effective and 3D printing the component was not time consuming. The final design was obtained after only 3 revisions of the visor mount. The first change corrected a small adjustment to the visor lens' curved mounting surface, and the second change added some needed tilt to the visor as well as a curvature adjustment to tightly fit the helmet frame.

Stage	Deliverable	Description	Who	Status	Due Date
1.0	**Finalization of idea**	**Discuss difficulty, feasibility, and utility of different project ideas, and decide as a group which project is the best fit for this course**	**All**	**Complete**	**17-May**
2.0	**Parts Selection**	**Search for components to put together. Ensure compatibility between parts.**	**All**	**Complete**	**22-May**
2.1	CV Research	Researched different options for Computer vision, comparing its accuracy, speed, and how powerful of hardware it needs to function.	Branden	Complete	22-May
	Microcontroller Choice	Choose a suitable microcontroller with ample IO and HW communication support for all required peripherals. Good library compatibility is required as well	Matthew	Complete	22-May
	Projection Design	Research methods for projecting onto a lens like a heads-up display. Decide on actual projection vs screen reflection. Make sure the required hardware fits in the budget, is small, and can be delivered expediently.	Jordan	Complete	22-May
2.2	Power System	Shop for suitable battery options, and feasibiility of developing our own battery battery system and charging circuit. See if there are small enough battereis with sufficient capacity without encumbering helmet safety and comfort.	Matthew	Complete	22-May
2.3	Order Parts	Order parts from afforable suppliers that can deliver quickly.	Jordan	Complete	23-May
2.4	Helmet Selection	Choose a bike helmet which will be able to house all our parts	Branden	In progress	24-Jul
2.5	Visor Selection	Choose a visor that will be able to reflect what is displayed on the OLED screen	Matthew	In progress	24-Jul
Web	Webpage Template	Find a suitable template we can modify to showcases our project	Branden	Complete	6-Jun
3.0	**Part Testing**	**Ensure all parts work individually, then ensure they are compatible by runnin simple tests such as passing UART messages between them, or displaying a digit sent from a microcontroller to a screen.**	**Matthew, Jordan**	**Complete**	**6-Jun**
3.1	Git	Open a GitHub page for keeping a version control system for our code, and keeping the public test code to build off of.	All	Complete	6-Jun
3.2	Huskylens Training	Teach the Huskylens to identify approaching cars	All	Future work	10-Jul
	Left/Right Display	Program OLED screen to display a warning arrow for left and right	Jordan	Complete	12-Jul
	Power Supply	Hook up power supply to power all microcontrollers and peripherals. Including any modifications	Branden	Future work	17-Jul
	Hardware Communications	Program all devices to communicate messages between each other, and parse said messages so that certain commands can be executed	Matthew	Future work	24-Jul
3.3	System Testing	Test system is fully functional as a whole	All	Future work	29-Jul
Web	Webpage Description	Add project description and background info to the website	Jordan	Future work	1-Aug
Web	Webpage Graphics	Touch up UX/UI on website, add images of progress and extra background information on the devices used.	Matthew	Future work	1-Aug
4.0	**Demonstration**	**Pubilcly present the project**	**All**	**Future work**	**29-Jul**
Web	Finalize Webpage	Add finishing touches and pictures of the final product to the webpage	Branden	Future work	5-Aug

Figure 1: Team Duties and Project Planning with Due Dates.

VI Design Methodology & Analysis

The following subsections will describe in detail the methods used in various design steps of the project.

Custom Parts

The design of the custom parts was done using Autodesk's Fusion 360, which is a 3D modeling software capable of designing individual parts and assembled of multiple part models. Fusion 360 is also a cloud based modeling software, meaning that all the project files can be accessed from any device if the user is signed into an authorized account. This software was used since its functions allow for easy group member contributions. To obtain the correct fitment of the components, a digital vernier caliper was used to measure the parameters of the helmet and visor and recorded on paper. These measurements were then used in the design of the 3D model for the specific part. Once all the parts were modeled, the measurements were then double checked against the helmet's dimensions using the calipers. Any minor fitment adjustments to base dimensions were corrected by means of trial and error. The final parts were then exported to a .stl file type and formatted into G code by means of a slicing software. Cura is the slicing software used here, it is free and full of useful printing functions. The software takes .stl models and converts them to G code given the user assigned printing preferences. The models are then printed using a fused deposition modeling (FDM) printer. FDM printers use spools of extruded plastic called filament, the filament is fed into a heated nozzle which extrudes a fine string of plastic onto the print surface, thus printing the model. The filament used for the final parts is black PLA, which has suitable properties for small prototype components.

Code

All coding aspects of this project, including testing code, examples, libraries, and the main project code is shared via GitHub repository. The repository allows for all group members to easily contribute and make alterations to the code while also maintaining proper revising tracking for the project. The programming environment used by each member was Visual Studio Code (VS Code), a free and highly supported development environment for coding. A plugin for VS Code called Platform IO was also used to create the embedded C projects, compile, and upload to the ATmega328 microcontroller onboard the Arduino NANO. Platform IO provided the easiest and most documented resource for embedded coding and was chosen unanimously by the group. Each time a group member made changes to the code, they were required to add a comment to their GitHub upload, describing in detail the changes made to ensure proper documentation standards were met. Adequate code commenting was also required by each group member to help others understand the operation of the code.

HUD

The heads-up display is intended to give the rider a convenient safety feature that does not require them to take their eyes or attention away from the road ahead of them. Importantly, the display should not impair the rider's vision or be distracting. In addition to this, the indicator should be easily visible to the rider and a clear image should be projected into the user's field of view. Testing the display using trial and error from various mounting locations allowed the team to understand several important aspects of projecting a virtual image onto a transparent surface. One important aspect was the brightness of the projected display. The light intensity of the display decreases significantly as the distance of the OLED screen from the visor increases. The team also found that the OLED screen's angle of incidence with the visor could cause the image to be distorted in the rider's view. Lastly, it was noticed that it is important the display be only visible with one eye, or else the image would appear doubled and blurry. Therefore, to create the effect of a crisp virtual image appearing to be projected into the rider's view, the team focused on making the projection exclusive to one eye's view to avoid a double image. The team found it difficult to perform calculations for obtaining an appropriate virtual image. With so many unknown properties of the selected lens, much of the design methodology was confirmed through trial and error. Testing the helmet with different visor angles and distances yielded crucial results that were used for designing a functional heads-up display.

Assembly

The assembly of the helmet plays a crucial role in the final project's overall functionality. For example, if the helmet assembly is bulky and has large protrusions, it could become a hazard to the rider. Therefore, the helmet's layout must be slim, lightweight, and keep the aesthetics of the original biking helmet. Another important principle with wearable tech is that it must look and feel aesthetic and stylish. In keeping with the original look of the stock helmet, the electronic components are protected in case the rider does crash, the components will still be enclosed within the air vents of the helmet. Additionally, the outer shell of the helmet was not modified, so the structural integrity was kept intact. The only modifications to the helmet were adding 3D printed components under the helmet's sunshade to hold the visor and cutting out a small amount of foam in the back to hold the Huskylens and battery. To ensure the electronics would fit without impacting the comfort of the helmet, the depth of the foam was measured by sliding a ruler from the inside of the helmet until it reached the shell on the outside, then the depth of the foam was noted, and the height of the components were measured using calipers. An outline of the component was then traced along the foam, which was then cut out using an Exacto knife. The components friction fit into the cut-outs and then the wires were routed along the fitment strap of the helmet to connect the Huskylens and battery at the back to the Arduino and OLED at the side and front, respectively. Following these techniques of internal routing, friction fitting within the foam, and only adding parts under the sunshade, the structural integrity of the helmet was kept intact, as well as the style and comfort.

VII Design & Prototype

The final prototype for this project was successfully created and tested after the intense design and assembly was accomplished. The code was written and successfully tested with the aid of a serial monitor to ensure the I2C communication bus was functioning between the Huskylens, OLED display, and microcontroller. The Huskylens was then trained to detect the front of a car and the operation of the microcontroller's object processing routine was validated. The object's approach was correctly determined, and the corresponding indicator symbol was monitored on the OLED display. The functionality of the HUD was then assessed by wearing the helmet and triggering an object detection manually. The HUD was found to function correctly in evening and lower light situations, however, when the ambient lighting levels are too bright, the reflected image is overpowered and lost to the rider's vision. The battery pack's function was tested by powering up the complete and running system and leaving it running until the battery was drained. The single 18650 cell supplied plenty of power storage for testing and prototyping purposes by keeping the device powered up for up to 5-6 hours without recharging. Overall, the device successfully increased riders' awareness on the road by correctly detecting oncoming vehicles and indicating the information to the rider. The safety of the rider was in turn increased due to the added blind spot detection, though, there was not enough time or testing data to justify the claim that the device reduces the amount of collisions between bikers and vehicles. However, a fully functioning wearable, blind spot detection, AR bike helmet prototype was successfully designed, created, and tested by the group (see figure 2).

Figure 2: AR Bike Helmet Prototype Showing Visor, 3D Printed Parts, and Microcontroller.

VIII Testing & Validation

Testing details and methods used will be discussed in detail in the following subsections.

Huskylens

The Huskylens came ready to use out of the box. For the testing, the group simply had to get familiar with training the unit to identify approaching cars. Thankfully, DFRobot provides lots of support and "getting started" guides to help learn its functionality.

Various objects were used for testing the object recognition feature, which classified objects into preloaded categories such as cars, bottles, computers, people, ect. It was later decided that using the object tracking mode provided better functionality for the purposes of this report, which allowed the Huskylens to identify custom selected objects and neglect any other objects being tracked.

OLED

The group began by uploading Adafruit example code to the Arduino and ensuring all pixels worked on the OLED. This was done by running through the Adafruit examples, then uploading code that activated all pixels to ensure none were dead. Since these are single colour pixels, there was no colour checking required.

Reflection and projection

The projection testing was done over a trial-and-error period first by holding the OLED display manually, then adjusting the position with a bracket connected to the OLED screen. The display had to be out of the user's sight, far enough from the user's head as to not make contact, and it had to clearly reflect an arrow such that the user could easily identify if it were left or right. Our group ran into issues by first assuming the display had to be close to the visor to give a clear display of the reflected arrow. What was found through testing was that the screen was still able to give a clear reflection if it were farther from the visor. The image would also appear larger, but still had to ensure that the arrow was only visible in one eye, otherwise the arrow would be blurry and difficult to tell left from right. To accomplish this, the OLED screen and visor was positioned in such a way that it reflected properly in the right eye, but the left eye would be looking under the bridge of the glasses, obstructing its view of the arrow.

The final position had the OLED out of sight, above the right eye, but still made a noticeable and clear arrow in the right side of the view. Velcro straps were added to the visor so it could be tilted; this allowed for the display to work with different head shapes, eye levels, and pupillary distances.

Power Supply

The power supply's cell was tested with a voltmeter once the battery was fully charged. It read 4.2V (which is standard for 3.7V LiPos at 100% charge). The charging circuit was also tested by letting the battery charge from completely empty to completely full, while ensuring the cell was not getting hot to the touch. Then it was fully depleted by plugging an iPhone in to charge. This test was repeated twice and passed both times. This ties into the first principle of the EGBC Code of Ethics: Act in the public interest (see appendix A), as the project is mainly concerned with an overheating or even exploding battery which would be catastrophic due to the battery's proximity to the user's head.

The helmet's components were tested once again with the battery before assembly by letting the fully functional system run overnight (6 hours). It passed with approximately >20% battery life left, which concluded that a single 2600mAh battery provides enough power storage for the project.

IX Cost Analysis

The project included direct costs only covering the components used, which are tabulated below:

Part	**Price**
Huskylens	$70
OLED Display	$7
KeeYees Arduino Nano	$10
Battery Pack	$20
Bike helmet	$70
3D printed materials	$5
Visor	$3
TOTAL	**$185**

Indirect costs were equally simple, with the only cost being hours worked. Our group averaged 10 hours a week each. At a rate of $25 an hour for 3 group members over the course of 8 weeks we total $6,000 for labour on the design and assembly.
The group received no external funding for this project nor any consulting.
Assembly of 20 of these helmets is possible in an 8-hour day, provided all the parts are readily available. If these helmets are priced at $250, and assuming they sell as quickly as they are produced, a ROI would take 12 days. This extremely quick payback is only

possible because of the assumption that a high volume is sold, the short timeframe of the project, and Co-op student wages.

This ROI could be lowered if parts were to be ordered in bulk directly from manufacturers. The price of the Huskylens and bike helmet could be drastically reduced. The same goes for the battery pack by designing a custom power PCB. If the group were to do this, the design hours and indirect costs must be revaluated. This design could further be optimized by designing a custom Arduino Nano board, as it would only need I2C and power ports, it would also be feasible to put the battery and charging circuitry on the same PCB as the microcontroller. However, due to the ongoing semiconductor shortage and short time of the project, it is not recommended to proceed with this.

X Conclusion & Recommendations

This bike helmet was designed and prototyped for the purpose of helping to protect cyclists in a world of transportation dominated by cars. Bicycle usership in urban areas is in part directly related to their safety on the road. Therefore, one of the best ways to encourage cycling in transportation and recreation is to elevate a cyclist’s spatial awareness while riding. Testing of this project exhibited a successful prototype in real world scenarios. The helmet was capable of detecting vehicles approaching from the user’s rear and would then effectively notify the rider with the arrow indicator displayed on the helmet's visor. Such technology can be anticipated to provide enormous safety benefits for modern cyclists and as a result could have a strong effect on the number of cyclists on the road, the overall physical health of our communities and the mitigation of traffic congestion. Many factors are contributing to the increasing number of cyclists year to year and the number of accidents on our roadways is proportional. Furthermore, the introduction of E-Bikes in modern society has allowed for cyclists to reach greater speeds and, as a result, a larger emphasis is put on rider safety. Thus, there is an ever-increasing need for technological intervention in the safety and experience of the everyday bike rider.

Upon completion of this project a successful prototype was created implementing computer vision and heads-up display technologies to inform rides of oncoming vehicles in their blind spot. The microcontroller and its code performed as expected and correctly displayed the appropriate indicator on the HUD according to the Huskylens’ object tracking. The battery pack and charging circuitry functioned exceptionally keeping the system active for 6 hours during prototyping after a full charge. However, there where some noticeable flaws which require future work to solve. Areas for improvement entail making the visor lens larger, building housings for the electronic components to be concealed in, improve the display so that it can be seen in bright ambient lighting, and develop a method for the Huskylens camera to operate better in adverse outdoor conditions. It is important that the helmet works in a wide range of weather conditions to ensure biker safety when it is needed most, so further development into the weather proofness of the system should be done. The priority of future work would be given to improving the computer vision component in adverse conditions such as rain, bright sunlight, or fog. Despite the various possibilities for improvement the list is not limited to the previously mentioned features. With the previous points in mind and in the scope of our project goals, it is important to the team that this idea encourages the development of technologies with similar purpose and application.

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Appendices

A. Code of ethics of EGBC

ENGINEERS &
GEOSCIENTISTS
BRITISH COLUMBIA

CODE OF ETHICS

The Code of Ethics required under the *Professional Governance Act,* S.B.C. 2018, c. 47 and created in the Bylaws of Engineers and Geoscientists BC provides a set of principles that all registrants are required to follow.

A registrant must adhere to the following Code of Ethics:

Registrants must act at all times with fairness, courtesy and good faith toward all persons with whom the registrant has professional dealings, and in accordance with the public interest. Registrants must uphold the values of truth, honesty, and trustworthiness and safeguard human life and welfare and the environment. In keeping with these basic tenets, registrants must:

1. hold paramount the safety, health, and welfare of the public, including the protection of the environment and the promotion of health and safety in the workplace;
2. practice only in those fields where training and ability make the registrant professionally competent;
3. have regard for the common law and any applicable enactments, federal enactments, or enactments of another province;
4. have regard for applicable standards, policies, plans, and practices established by the government or Engineers and Geoscientists BC;
5. maintain competence in relevant specializations, including advances in the regulated practice and relevant science;
6. provide accurate information in respect of qualifications and experience;
7. provide professional opinions that distinguish between facts, assumptions, and opinions;
8. avoid situations and circumstances in which there is a real or perceived conflict of interest and ensure conflicts of interest, including perceived conflicts of interest, are properly disclosed and necessary measures are taken so a conflict of interest does not bias decisions or recommendations;
9. report to Engineers and Geoscientists BC and, if applicable, any other appropriate authority, if the registrant, on reasonable and probable grounds, believes that:
    a. the continued practice of a regulated practice by another registrant or other person, including firms and employers, might pose a risk of significant harm to the environment or to the health or safety of the public or a group of people; or
    b. a registrant or another individual has made decisions or engaged in practices which may be illegal or unethical;
10. present clearly to employers and clients the possible consequences if professional decisions or judgments are overruled or disregarded;
11. clearly identify each registrant who has contributed professional work, including recommendations, reports, statements, or opinions;
12. undertake work and documentation with due diligence and in accordance with any guidance developed to standardize professional documentation for the applicable profession; and
13. conduct themselves with fairness, courtesy, and good faith towards clients, colleagues, and others, give credit where it is due and accept, as well as give, honest and fair professional comment.

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B. Website link and the main page image

[AR Bike Helmet (brandenjvoss.github.io)](https://brandenjvoss.github.io)